Femoral neck fractures after arthroscopic femoral neck osteochondroplasty for femoroacetabular impingement

Zingg, Patrick O ; Buehler, Tobias C ; Poutawera, Vaughan R ; Alireza, Amin ; Dora, Claudio

Abstract: PURPOSE: The objective of this study was to evaluate the rate, associated risk factors and outcome of insufficiency femoral neck fractures following arthroscopic femoral neck osteochondroplasty for femoroacetabular impingement. METHODS: Between 2005 and 2009, a consecutive series of 376 arthroscopic femoral osteochondroplasties for femoroacetabular impingement were performed and analysed. Seven postoperative fractures were found and comprise the fracture group. The amount of femoral head-neck bone resected as assessed on follow-up cross table lateral views, as well as age, gender, height, weight and BMI, was compared between the fracture group and the entire collective. Subjective outcome was recorded using the WOMAC score. RESULTS: Seven fractures (1.9 %) were identified. All occurred in males at an average of 4.4 weeks postoperatively and were considered insufficiency fractures. The fracture group had a significantly higher mean age ($p = 0.01$) and height ($p = 0.013$). Within the fracture group, alpha angles were lower ($p = 0.009$) and resection depth ratios were higher ($p < 0.001$). The femoral offset was significantly higher ($p = 0.016$) in the fracture group and in male patients ($p < 0.001$). The cut-off value for resection depth ratio on cross table lateral radiograph was 18 % of the femoral head radius. After a mean follow-up of 20 months, an inferior WOMAC ($p = 0.030$) was recorded in the fracture group. CONCLUSION: Femoral neck insufficiency fractures were identified in 1.9 % of our arthroscopic femoral osteochondroplasty cases. Significant new pain following a period of satisfactory recovery after arthroscopic femoral neck osteochondroplasty should alert the surgeon to the possibility of this complication. If a resection depth ratio of more than 18 % is recognized on the postoperative cross table lateral view, particularly in male patients with a high femoral head-shaft offset, the risk of postoperative insufficiency fracture is increased. This study not only defines the complication rate, but also identifies associated risk factors and determines the influence on the postoperative subjective short-term result. Important information for both the patient and orthopaedic surgeon is provided and may have a direct consequence on the postoperative protocol. LEVEL OF EVIDENCE: IV.

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HIP

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Patrick O. Zingg · Tobias C. Buehler · Vaughan R. Poutawera · Amin Alireza · Claudio Dora

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Results Seven fractures (1.9 %) were identified. All occurred in males at an average of 4.4 weeks postoperatively and were considered insufficiency fractures. The fracture group had a significantly higher mean age ($p = 0.01$) and height ($p = 0.013$). Within the fracture group, alpha angles were lower ($p = 0.009$) and resection depth ratios were higher ($p < 0.001$). The femoral offset was significantly higher ($p = 0.016$) in the fracture group and in male patients ($p < 0.001$). The cut-off value for resection depth ratio on cross table lateral radiograph was 18 % of the femoral head radius. After a mean follow-up of 20 months, an inferior WOMAC ($p = 0.030$) was recorded in the fracture group.
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Level of evidence IV.

Keywords Hip arthroscopy · Femoroacetabular impingement · Complication · Femoral neck fracture

P. O. Zingg (✉) · T. C. Buehler · C. Dora
Department of Orthopaedics, University of Zurich Balgrist, Forchstrasse 340, 8008 Zurich, Switzerland
e-mail: patrick.zingg@balgrist.ch

V. R. Poutawera
Department of Orthopaedics, Tauranga Hospital, Tauranga, New Zealand

A. Alireza
Department of Orthopaedic Surgery, Tehran University, Tehran, Iran

Introduction

Evidence that femoroacetabular impingement (FAI) causes mechanical hip pain [11] and contributes towards the onset of osteoarthritis continues to mount [10, 11, 24, 25]. In so-called CAM impingement, the non-spherical head-neck junction repetitively abuts the acetabular rim, resulting in a shearing injury to the labrum and adjacent articular cartilage [2]. Resection of the osteochondral "bump" with a femoral osteochondroplasty of the head-neck junction to improve the head-neck ratio, and increase the range of motion before impingement [3], has been described utilizing both open and arthroscopic techniques [6, 11, 15, 16, 20].

Despite theoretical concerns that femoral neck osteochondroplasty might increase the susceptibility of the femoral neck to fracture, very few published clinical series [1, 12, 17, 22] dealing with femoral neck osteochondroplasty have reported this complication.

In our institution, arthroscopic femoral neck osteochondroplasty for CAM-type FAI has been performed since 2005 and femoral neck insufficiency fractures (Figs. 1, 2) have been recognized as a rare complication.

The purpose of this study was to evaluate the rate, associated factors and the influence of postoperative insufficiency fractures on short-term outcome following arthroscopic femoral osteochondroplasty. It was hypothesized that extensive bony resection, older age and heavy weight might be associated risk factors for such fractures.

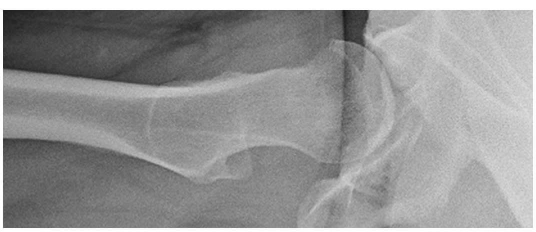

Fig. 1 Postoperative radiograph of fracture group

Fig. 2 MRT of insufficiency femoral neck fracture after arthroscopic osteochondroplasty for FAI

Materials and methods

From a prospectively acquired computerized database, a consecutive series of 430 hip arthroscopies (420 patients) performed between 2005 and 2009 were identified. Fifty-four hip arthroscopies were excluded as no femoral neck osteochondroplasty was performed. In these cases, arthroscopy was limited to debridement of the labrum and/or trimming of the acetabular rim, arthroscopic debridement of intra-articular PVNS lesions, arthroscopic debridement and partial capsulectomy for septic arthritis, and diagnostic arthroscopy. In the remaining 376 hip arthroscopies (357 patients), femoral neck osteochondroplasty was performed in isolation or in addition to trimming of the acetabular rim. These patients comprise the osteochondroplasty group. The subset of patients from the osteochondroplasty group identified to have sustained a femoral neck fracture during their rehabilitation comprises the fracture group. All patients in the fracture group had magnetic resonance tomography showing the typical appearance of an insufficiency fracture.

All hip arthroscopies were performed by two experienced hip surgeons. Patient positioning and portal placement were performed according to Byrd [5] under general anaesthesia. Initially, arthroscopy of the central compartment was performed under traction and pincer deformities addressed as needed by acetabular rim trimming. Subsequently, femoral osteochondroplasty was performed without traction along the anterolateral femoral neck taking care not to compromise the posterosuperior retinacular vessels. Bony resection was judged adequate when, by dynamic examination and with direct visualization, an impingement-free internal rotation of at least 30° was achieved with the hip flexed to 90°. The postoperative rehabilitation protocol directed patients to weight bear as tolerated on two crutches and ride on a bicycle ergometer twice a day for 6 weeks to maintain hip motion. Indomethacin 75 mg and enoxaparin 40 mg were prescribed on a daily basis for 2 weeks in order to prevent heterotopic ossification and thromboembolic complications.

Demographic factors potentially associated with femoral neck fractures including age, gender, height, weight and BMI were recorded for all patients. In order to identify morphological factors associated with femoral neck fractures, the extent of bony resection at the head-neck junction in all patients was assessed at 12-month follow-up or at the time an insufficiency fracture had occurred, respectively. The alpha angle, resection depth and the resection depth ratio (Fig. 3) were measured on cross table lateral views. The CCD angle and the femoral head-shaft offset were measured on AP pelvic radiograph.

Using the WOMAC [4], the subjective outcome was assessed after a minimal follow-up of 12 months and

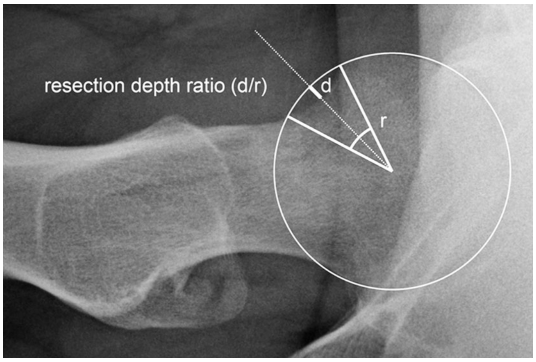

Fig. 3 Measurement of resection depth and resection depth ratio on a cross table radiograph

compared between the fracture and the osteochondroplasty group.

Statistical analysis

A statistical consultant performed all statistical analyses. The Mann–Whitney *U* test was performed to evaluate differences of continuous data between groups. The Wilcoxon signed-rank test was used to compare continuous paired data between groups. In order to define cut-off values for factors associated with the occurrence of femoral neck fracture, receiver-operating characteristic (ROC) curves were drawn. Risk estimate was calculated for cut-off values, and asymptotic confidence interval was recalculated with bootstrap (based on 10,000 bootstrap samples). For all statistical tests, significance was set at $p < 0.05$.

Results

Femoral neck fractures occurred in 7 of 376 arthroscopic femoral neck osteochondroplasties resulting in a fracture rate of 1.9 %. Three patients had a history of very minor trauma resulting in increased hip pain. Two developed pain after stumbling, and one whilst exercising gently on a trampoline. Four patients could not remember any specific incident which provoked their renewed pain. In all, the onset of significant new pain following a period of satisfactory recovery motivated us to perform a MRT revealing the fracture lines and oedema consistent with an insufficiency fracture (Figs. 1, 2). The fractures were all non-displaced and occurred at a mean of 4.4 weeks (SD ± 3.6). Whilst the first two fractures (tension type) were managed by in situ fixation, the following 5 (compression type) were treated conservatively with simple analgesia and restricted weight bearing on 2 crutches for 6 weeks. All fractures healed uneventfully. Six months after fracture, one of the seven patients underwent an arthroscopic adhesiolysis, following which his residual symptoms and hip function substantially improved.

Table 1 Demographics: fracture group and osteochondroplasty group

	FG ($n = 7$)		OG ($n = 370$)		p value
	Mean	SD	Mean	SD	
Male (%)	100.0	–	43.0	–	0.003
Age (year)	44.1	10.1	34.7	10.7	0.010
Height (cm)	180.0	4.7	172.5	9.2	0.013
Weight (kg)	82.6	10.1	72.8	15.3	n.s.
BMI (kg/m^2)	25.6	4.9	24.3	3.9	n.s.

Table 2 Amount of bone resection on cross table view: fracture group and osteochondroplasty group

	FG (n = 7)		OG (n = 370)		p value
	Mean	SD	Mean	SD	
Alpha angle (°)	34.7	4.1	40.6	6.4	0.009
Resection depth (mm)	6.2	1.5	3.5	1.7	<0.001
Resection depth ratio (%)	21.8	4.9	13.2	6.4	<0.001
CCD angle (°)	130.1	6.6	126.6	6.9	n.s.
Offset (mm)	45.8	6.8	52.3	6.7	0.016

Patient's demographics are summarized in Table 1. Compared to the whole osteochondroplasty group, all patients of the fracture group were male ($p = 0.003$) and were significantly older ($p = 0.01$) and significantly taller ($p = 0.013$). There were no significant differences with respect to weight and BMI between the two groups.

Differences in the extent of head-neck resection are summarized in Table 2. On the cross table lateral radiograph, the mean resection depth ratio was significantly higher ($p < 0.001$) in the fracture group. The average of all alpha angles measured was significantly lower in the fracture group ($p = 0.009$). Femoral offset was significantly higher ($p = 0.016$) in the fracture group and in male patients (m: 49.3 mm ± 6.6; f: 43.1 mm ± 5.6; $p < 0.001$).

For predicting fracture risk, cut-off values resulting from ROC curves for age, resection depth ratio and femoral offset were 45 years with a odds ratio of 22.8 (95 % CI 3.5–42.5), 18 % resection depth ratio on cross table lateral view with a odds ratio of 25.6 (95 % CI 3.8–47.9) and femoral offset of 48 mm with a odds ration of 10.8 (95 % CI 1.3–91.1).

Preoperative WOMAC did not significantly differ between the fracture group (mean 3.4, SD ± 2.7) and the total osteochondroplasty group (mean 3.1, SD ± 2.9). After a mean follow-up time of 20 months (SD ± 11.46), the overall WOMAC ($p = 0.034$) as well as its sub-scores for pain ($p = 0.022$) and function ($p = 0.017$) was significantly worse in the fracture group. When comparing the difference between the preoperative and follow-up WOMAC scores (postoperative fracture group mean 3.4, SD $\pm$ 2.1; osteochondroplasty group mean 2.0, SD $\pm$ 2.2,), the total osteochondroplasty group showed significant improvement ($p < 0.001$), whereas the fracture group did not.

Discussion

This study is the first to report the incidence, risk factors for, and outcome following femoral neck fracture after arthroscopic femoral osteochondroplasty. The most important finding of the present study was that the fracture rate was higher than expected. More extensive bony resection and older age were, as hypothesized, found to be associated risk factors for fracture. Male gender, greater height and femoral head-shaft offset were also identified as associated factors. Interestingly no significant difference was found with regard to weight or BMI between the groups. The short-term outcome was found to be less favourable in the fracture group.

The present study reveals a fracture rate of 1.9 % in a consecutive series of 376 femoral neck osteochondroplasties. This is higher than reported in the literature: one out of 100 in Laude et al. [17], 1 of 111 in Gedouin et al. [12], 1 of 158 in Sampson et al. [22] and 1 of 1500 in Ayeni et al. [1]. The rather aggressive postoperative protocol with weight bearing as tolerated prescribed in the present series may be an explanation for this high rate. Inappropriately excessive femoral neck bone resection may of course explain the fractures. It is possible also that other series have underestimated the rate of fracture as the symptoms may be relatively minor and may be masked by a prolonged postoperative course.

Femoral osteochondroplasty aims to accomplish perfect sphericity of the femoral head with a smooth head-neck junction in order to resolve the symptoms of FAI. Since most revision arthroscopies in patients with poor results are performed because of under-resection of the CAM lesion [13, 14, 17, 19], there may be tendency towards more aggressive resection of the osteochondral bump. On the other hand, overcorrection by undercutting the ideally convex head-neck surface is unwelcome, irreversible, and may be an issue with regard to loss of joint sealing effect, potentially negatively influencing long-term outcome [23]. Fractures were associated with a higher extent of head-neck resection in the present series. In terms of the resection depth ratio on lateral cross table lateral radiographs, ROC curves revealed that a resection depth ratio of greater than 18 % increased the risk of fracture by a factor of 25. This cut-off is much less than the resection value identified in Mardones' et al. [18] biomechanical study which reported that a resection depth ratio of 30 % was unlikely to result in a femoral neck fracture. However, Mardones' et al. experimental setting acquired a load to failure curve that may not correspond to the cyclic loading in the clinical setting, and this may explain why we identified fractures in patients with bony resection depth of less than 30 %. Moreover, Mardones' et al. study was limited to investigate the fracture risk depending on resection depth only, whereas resection depth, length and width were not considered in combination. In a study by Akcakoyunlu et al. [21], the influence of resection geometry on fracture risk after osteochondroplasty in a finite element study was studied taking into account depth, width and length. It has been shown that resection depth alone is an insufficient determinant of postoperative bony resistance. Resection of more than 20 % of the diameter should be avoided, since fracture may occur even with shallow resection depths (10 %) in cases of even very minor trauma such as stumbling. This is in accordance with the findings of our study.

Male gender and older age were both significantly associated with femoral neck fracture in our investigation. Unfortunately, the four other reports mentioning a femoral neck fracture after osteochondroplasty lack detailed patient information. The patient in the study by Laude et al. [17] was 56 years old, however, gender was not reported; the patient in the report of Goudin et al. [12] was female, but her age was not stated; the patient in the report of Ayeni et al. [1] was a 51-year-old man, and for the patient in the Sampson et al. paper [22], no demographic data were given. Therefore, no comparison can be made with our data. The fact that both high femoral offset and greater height are associated factors for fracture, and both parameters were significantly higher in males, may explain the gender association identified.

In this series, all fractures were non-displaced. They were classified as insufficiency fractures, since they occurred in postoperatively weakened and therefore abnormal bone during normal activities of daily living. The two first cases were tension-type fractures and managed by in situ fixation [7, 8]. Tension-type fractures are potentially unstable and typically require internal fixation [7, 8]. However, non-operative treatment with limited weight bearing may also be considered when the fracture is not visible on conventional radiographs but apparent on scintigraphy [9] or MRT only. The succeeding 5 cases involved a more stable compression type fracture allowing for non-operative management [7, 8]. Therefore, conservative treatment with simple analgesia and restricted weight bearing on 2 crutches for 6 weeks was instituted. All fractures healed uneventfully.

Femoral neck fractures after osteochondroplasty were associated with significantly worse short-term subjective outcome. Formation of callus, scar and adhesions between capsule and femoral neck after fracture may explain this inferior short-term outcome.

Several limitations to this study are recognized. First, the small number of patients sustaining fractures in the present series limits its power since neither multivariate analysis nor logistic regression could be applied on this data set. However, post hoc power analysis revealed 65 % power for the parameter resection depth ratio and 62 % for the parameter femoral offset with a relevant difference assumed of 5 % and 5 mm, respectively. Second, postoperative radially reconstructed MRT reformations of the anterolateral femoral head-neck junction would have been preferable to quantify the amount of bony neck resection of the whole collective. Valuable information not only on resection depth but also on width and length with regard to different sectors could have been determined more accurately. However, additional postoperative MRT imaging was not performed in asymptomatic patients with uneventful postoperative courses. Third, generally the load bearing properties of the bone depend on both the geometrical size and the mechanical quality of the tissue. Only the influence of the size of the femoral head-neck junction on fracture risk has been evaluated in this study population.

Conclusion

Insufficiency fractures of the femoral neck after arthroscopic femoral osteochondroplasty occur more frequently than might be expected from previously published studies. Significant new pain following a period of satisfactory recovery should alert the surgeon to the possibility of this complication. Associated risks for fracture include greater bone resection, older age, male gender, increased height and increased femoral offset. If a resection depth ratio of more than 18 % is recognized on the postoperative cross table lateral view, particularly in an older male with a femoral offset than 48 mm, the risk for postoperative insufficiency fracture is increased.

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